

ON THE TAXONOMIC VALUE OF THE MORPHOLOGY OF WING SCALES IN SOME HELICONIINAE (LEPIDOPTERA, NYMPHALIDAE)

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ABSTRACT

Wing scales of particular Brazilian *Heliconius erato* (Linnaeus, 1758) and *H. besckei* (Ménétriés, 1857) (Lepidoptera: Nymphalidae) forms were comparatively analyzed. Scales taken from the red postdiscal forewing recto band did morphologically not differ between sexes, species or localities whereas red scales from the hind wing verso surfaces strikingly differed between the two species investigated. Black and grey scales of each of the taxa/sexes that were taken from the basal area of the hind wing verso surfaces differed among sexes and among species. The findings are discussed in the context of the possible thermoregulatory and the aerodynamic property of wing scales.

KEYWORDS. *Heliconius*, scales, Taxonomy, Brazil.

INTRODUCTION

One of the principal characters used in taxonomic studies on butterflies is the morphology of the male genital apparatus. It is highly conserved within species and therefore, its anatomical investigation normally warrants a correct identification of a given specimen with regard to its specific status. Nonetheless, sibling species can frequently only be discerned from each other by considering long series of each taxon, taking into account a variety of geographical, ecological and morphological features, particularly concerning the morphology and biology of immature stages. With regard to adult and preserved specimens, as mostly found in collections, however, nothing but the genital apparatus and the outer appearance can be subjected to comparative investigations since geographical and ecological informations upon preserved specimens are normally kept to the minimum and the larval stages are often not known. ANKEN (1995a, b) found out, that the morphology of homologous scales (squamulae) in the sibling species *Pieris rapae* (Linnaeus, 1758) and *P. napi* (Linnaeus, 1758), all taken in southwestern Germany, obviously varied according to their shape. The noted differences between the scale morphology were therefore regarded as a species-distinctive feature, the both species

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being discernible from each other by the shape of scales rather than by the morphology of the genital apparatus.

ANKEN & BREMEN (in press) add some information to the question, to which extent homologous scales differ in more or less closely related nonsibling species. In agreement with GRODNITSKY & KOZLOV (1991), that study revealed a remarkable taxonomic value of the scale-morphology among members of Papilionidae, since they do not use scales as thermoregulatory elements as other butterflies and most moths do. The morphology of Pieridae and Papilionidae scales are therefore rather due to functionally indifferent evolutionary radiations than to an adaptation to thermoregulatory pressures.

The scale-morphology of some tropic Nymphalidae, who also might not use scales for thermoregulation (GRODNITSKY & KOZLOV, 1991) was investigated, focusing on sibling species of the genus *Heliconius* (Kluk, 1802) in order to find out, if they can be discriminated by their scale morphology and to contribute to the question, what the biological relevance of scales might be.

MATERIAL AND METHODS

The nomenclature follows SMART (1977) with regard to the subspecific rank attributed to *Heliconius melpomene phyllis* (Fabricius, 1775). It is beyond the scope of this investigation to prove this systematic positioning, but to use the names merely in order to state as exactly as possible the individual taxon, so that a reader may discriminate and recognize them without being fogged by nomenclatural terms only intelligible to the specialist. Therefore, all authors of a given form, subspecies and species are stated in the following, even if this is not carried out fully according to the rules of Zoological Nomenclature. The taxa are common in Brazil. All specimens used were collected by the author and they are deposited in his private collection.

The following forms (only fresh individuals without external signs of being worn) were investigated: BRAZIL. Mato Grosso do Sul: Navirai, 7 ♂ of *Heliconius erato phyllis* f. *artifex* (Stichel, 1909), 26. X. 1993. Paraná: Foz do Iguaçu, 5 ♂ of *H. besckei* (Ménétriés, 1857), 26.X.1993; 3 ♀ of *Heliconius erato phyllis* f. *artifex*, 26.X.1993; 6 ♂ of *Heliconius erato phyllis* f. *artifex*, 26.X.1993.

The protocol to take scales follows ANKEN (1995b). The scales to be investigated were taken from (1) the red postdiscal forewing recto band, (2) the red spots of the basal area of the hind wing verso, and (3) from the blackish grey vicinity of the scales of (2) by a moistened brush. After having been transferred to microscopical slides, they were allowed to dry and were subsequently coverslipped using Hydromatrix. From each experimental group (i.e., species/geographical population/sex), at least three individuals were analyzed concerning the respective morphology of the squamulae. Therefore, at least thirty individual scales per individual were drawn using a camera lucida equipped binocular transmission light microscope at a magnification of 400x. The drawn series-images (called SI in the following) were coded, compared to each other and any observations were noted. The coding was employed in order to prevent the experimenter of knowing the specific name of an SI, which might unwillingly have led to biased results. The results obtained were attributed to the respective experimental group. The SIs in the figures comprise randomly chosen scales of randomly chosen individuals of each animal group. In the course of extensive preliminary examinations, it had been found out, that such short SIs are satisfactorily suited to demonstrate the general morphological appearance of the scales of a given experimental group. Additionally to some SIs, composed images (CIs) were prepared by drawing one scale over the other by the use of a light-plate and transparent paper. The scales of a figured CI were the same as shown in the respective SI.

RESULTS

All scales analyzed reveal an apical field with more or less pronounced protrusions (processi), which vary among the same individual and from species to species. All postdiscal red forewing recto scales (figs. 1-4) are quite narrow and reveal several apical processi. Very few scales only have two processi (fig. 1, 12th. scale; this feature has only

been observed in female *H. erato*) and also extremely broad scales with more than four processi are uncommon but were found in all animals investigated (figs. 1-4, last scales). Any differences between the SIs of red forewing recto scales (figs. 1-4) are more clearly revealed regarding the respective CIs (figs. 9a-d). The CI of a female *H. erato* (fig. 9a: Paraná) resembles that of male *H. erato* individuals (fig. 9b: Paraná; fig. 9c: Mato Grosso do Sul), but the apical field looks not as variable as does the one in the males. The scales apical field of a male *H. besckei* specimen (fig. 9d: Paraná) appears quite homogeneous, indicating a low variety among different scales.

Red scales taken from the hind wing verso surfaces (figs. 5-8 and figs. 9e-h; SIs and CIs, respectively) do not only morphologically clearly differ from those of the forewing recto in being considerably larger. Moreover, they vary among the biological entities investigated much more thoroughly than the scales described before do: in female *H. erato* specimens, the scales are quite narrow and the processi are pronounced but extremely variable concerning their particular shape (figs. 5, 9e). Male *H. erato* butterflies from the same locality (Paraná) reveal broader scales and fang-like apical protrusions (figs. 6, 9f), whereas the homologous processi in male *H. erato* from Mato Grosso do Sul are thumb-like and vary considerably (figs. 7, 9g). Most strikingly, the scales from male *H. besckei* from Paraná do not reveal any protrusions at all (figs. 8, 9h).

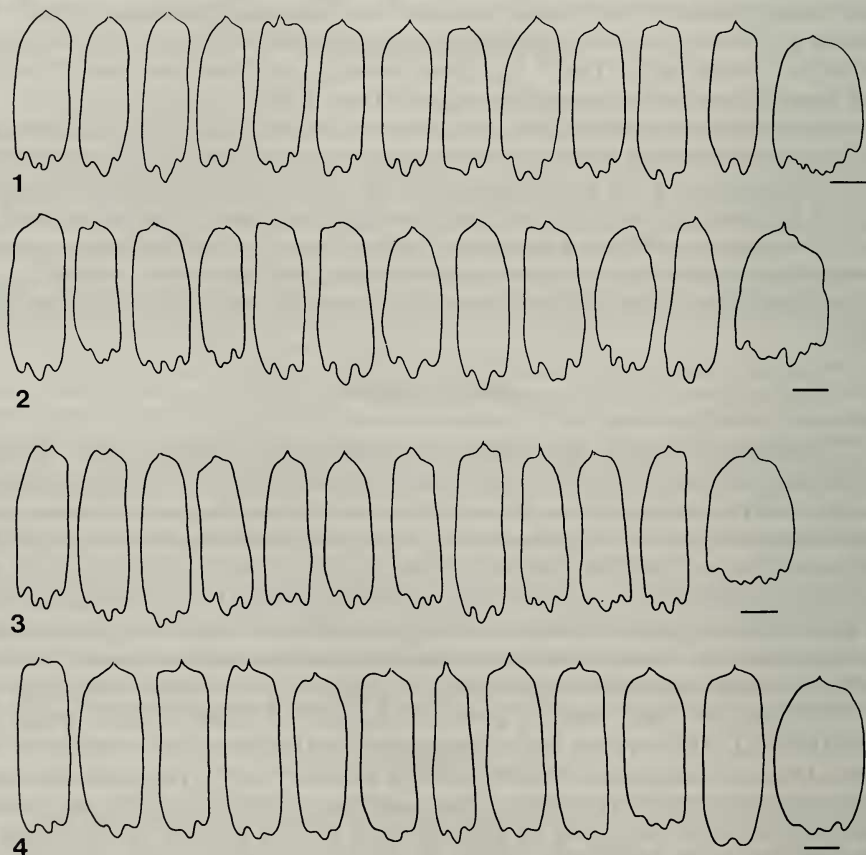
The variation among black and grey scales of each of the taxa/sexes that were taken from the basal area of the hindwing verso surfaces is overwhelmingly considerable (figs. 10-13). Nonetheless, it can be pointed out that the male *H. erato* specimens, although taken at different locations, to some extent resemble each other, whereas the male *H. besckei* has only two different kinds of greyish/black scales on the hind wing verso that do not strikingly differ from the other ones of this taxon and the female *H. erato* has scales not appearing in any other butterfly investigated, especially the narrow and broad giant scales.

DISCUSSION

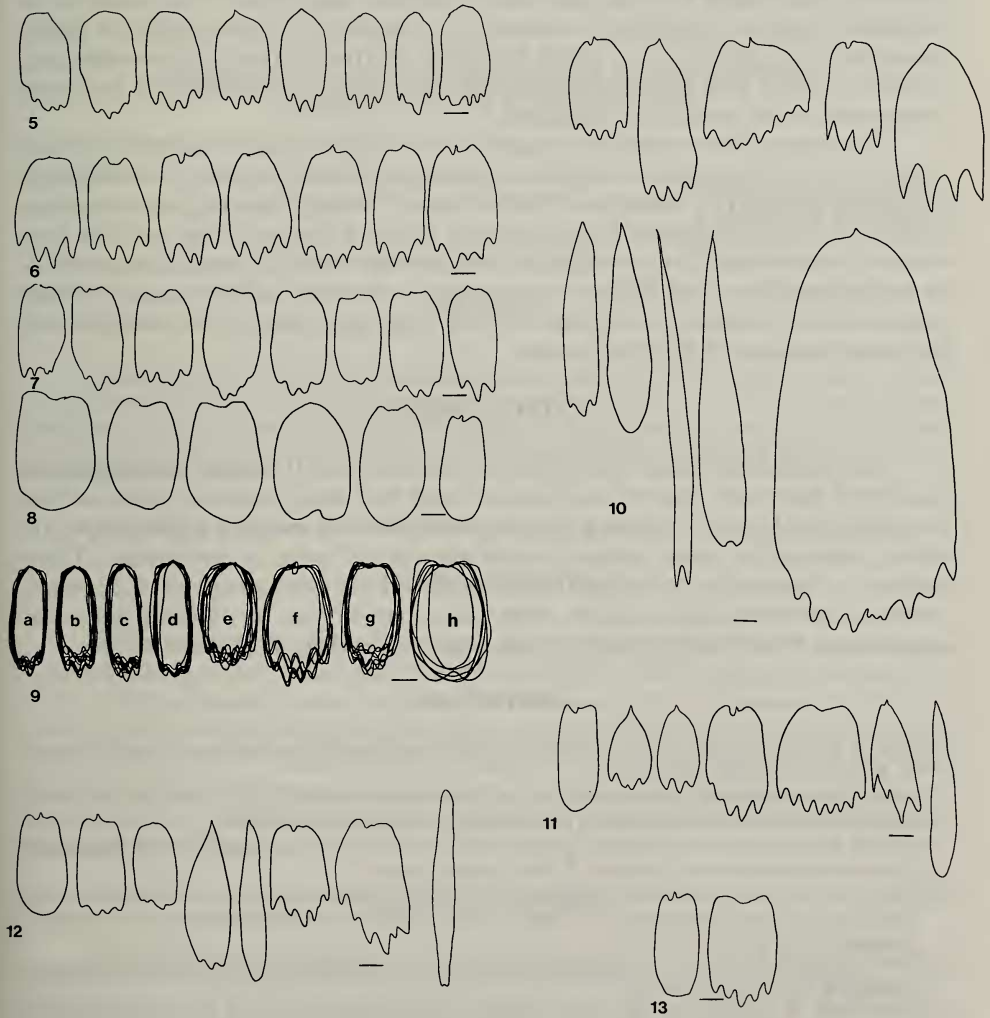
The red scales taken from the forewing recto only somewhat differ between *Heliconius erato* and *H. besckei*. Their variation among male *H. erato* from different localities and from male to female *H. erato* from the same locality is not presumed to be significant as well. Also a comparison among red scales from the basal area from the hind wing verso does not reveal any obvious differences among the *H. erato* specimens, but homologous scales from *H. besckei* strikingly differ. Regarding the scaly furnishment of the basal hind wing recto surface concerning other than red scales (i.e. greyish/black ones), *H. erato* has a variety of differently shaped scales (especially the female), whereas in *H. besckei* only some different and simply organized types of scales were found.

It is not yet clear, what the particular function of butterfly scales might be. NACHTIGALL (1967) argued, that scales in specialized butterflies may contribute to the physical basis of sailplaning. GRODNITSKY & KOZLOV (1991) proposed, that scales might prevent a butterfly from getting water soaked or glueing to a spiders net or resin. Most comprehensive and based on large amounts of data, however, is the theory of GRODNITSKY & KOZLOV (1991), according to which scales may act as thermoregulatory units. It is far beyond the scope of the given study to discuss the possible biological relevance of the scales investigated, but to clarify their possible use for

taxonomy. Nevertheless, it is intriguing that just the recto scales do not differ among the taxa/sexes/geographical entities investigated: members of the genus *Heliconius* frequently exhibit sailplaning behavior (according to NACHTIGALL, 1967, this behavior is substantially based on the aerodynamics of recto wing scales) and they take sunbaths with opened wings therewith exposing the recto surfaces and the respective scales to sun radiation (as not all butterflies do: some European satyrid *Hipparchia* spp., e.g., try to avoid sunshine directed to the recto surfaces but nevertheless place themselves to direct sunlight by collecting it by the verso surface; own observations). With that, the similarity in wing scale morphology regarding recto surfaces in *Heliconius* might be based on similar evolutionary pressures, i. e., similar functional requirements such as aerodynamics and gathering sun radiation derived heat. Since these environmental pressures may not affect the verso surface scales, their morphology might be due to functionally indifferent evolutionary radiations, consequently leading to a variety of morphological different



Figs. 1-4. Series images (SIs) of red scales. From postdiscal forewing recto band - *Heliconius erato phyllis*, Paraná: 1, ♀; 2, ♂; Mato Grosso: 3, ♂; 4, *H. besckei*, Paraná, ♂. Bars = 25 μ m.



Figs. 5-13. Series images (SIs) of red scales. From hind wing verso surfaces. *Heliconius erato phyllis*, Paraná: 5, ♀; 6, ♂; Mato Grosso: 7 ♂; 8, *H. besckei*, Paraná, ♂; 9, Composed images of the SIs shown in figs. 1-8. 10-13, (SIs, same animals in the same order). These SIs were taken from black and grey scales that were collected from the basal area of the hind wing verso surfaces. Bars = 25 µm.)

features concomitantly employed during the course of the evolution of functionally relevant features like the recto scales, the wing shape and the male genital apparatus. Especially functional indifferent attributes may be considered to be of taxonomic value, since function-related ones are liable to appear in similar fashions in taxonomically distantly related animals as analogous structures just do due to physical properties. The arguments used above may therefore explain a finding of the present study, according to which red scales taken from the hind wing verso basal area (which is estimated to be functionally irrelevant) clearly differ between *H. erato* and *H. besckei* indifferent on the sex and the geographical locality. EMSLEY (1964, 1965) pointed out that both sibling and congeneric species may be distinguished from each other by consulting the particular arrangement of red spots in this wing area.

The results of the present study clearly reveal a species-specific morphology of red scales taken from this particular wing area. Regarding individuals in doubt, an investigation on scales of this area may therefore add further data of obviously unambiguous taxonomic significance. An investigation of greyish/black scales of the same wing part also may warrant a secure identification on species level since the variety of these scales seems to be species-specific as well. Further investigations on the verso and recto scales of other conspecific and congeneric *Heliconius* will add some more data on the taxonomic and functional relevance of particular scales.

CONCLUSIONS

It is concluded, that the forms of *Heliconius erato* and *H. besckei* investigated are discernible from each other by the shape of basal hind wing verso red scales and the particular furnishment of this wing area with blackish scales revealing a species-specific variety, whereas the variety among female and male *H. erato* is less distinct. These findings, as compared to the findings regarding scales from the recto surface of the wings, where no species-specific features were seen, may be due to different functional requirements of verso and recto wing scales, the former being of taxonomic value.

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